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The surfaces $\overline{\Sigma}'$ and $\overline{\Sigma}'_1$ are in the relation of a transformation D_m. Let $\overline{S}$ be the surface of centers of the spheres of this transformation and $\overline{S}_0$ the deform of $\overline{S}$. Applying the above method to these surfaces, we find that the lines joining O to the points of $\overline{S}_0$ are parallel to the normals to Σ. Moreover, the surfaces $\overline{S}$ and S_0 correspond with parallelism of tangent planes; likewise $\overline{S}_0$ and S.

When $c \neq 0$ in (4), the surface Σ'_1 is an isothermic surface in the relation of a transformation T_m with Σ.

[1] Bianchi, *Geometria Differenziale*, **2**, 88.

[2] l. c., p. 117.

[3] Eisenhart, *Differential Geometry*, 122.

[4] *Théorie Générale des Surfaces*, **2**, 383.

[5] Darboux, *Ann. École Normale Supérieure*, ser. 3, **16** (1899).

[6] *Roma, Rend. Acc. Lincei*, ser. 5, **24**, 161 (1915).

[7] *Ann. Mat., Milano*, ser. 3, **12**, 19 (1906).

GEOGRAPHIC HISTORY OF THE SAN JUAN MOUNTAINS SINCE THE CLOSE OF THE MESOZOIC ERA

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The San Juan Mountains are located in the southwestern corner of Colorado. From their lofty summits one may look far off into Utah, Arizona, and New Mexico. The highest peak in the range, Uncompahgre, rises to an elevation of 14,300 feet above sea level. There are many other peaks whose summits are above 14,000 feet in elevation, and a large portion of the mountain area is more than 12,000 feet above sea level.

The core of the San Juan Mountains is composed of a complex series of pre-Cambrian gneisses, schists, quartzites, and granites, all of which have been more or less affected by intrusive bodies of igneous rocks. After this pre-Cambrian complex was so eroded that the relief in the region was low, the entire district was submerged and a great series of Paleozoic and Mesozoic strata was deposited over the once mountainous area.

At the close of the Mesozoic era and the opening of the Cenozoic era there were mountain-making movements which affected the entire Rocky Mountain province of North America, and the great dome which was then formed in the San Juan area was at once subjected to vigorous erosion. As the mountain mass rose erosion began, and as the great dome was more and more deeply dissected a mountain topography must have been produced, and those mountains may be thought of as the first generation of the San Juan range (see fig. 1). During the period of mountain growth there was some volcanism. Many porphyritic intrusions and the deposition of the great volcanic tuffs which made contributions to the Ridgway till date back to this period. The Eocene till indicates that during the dissection of these early San Juan Mountains ice formed in the range and descended to the bordering lowlands. Possibly ice formed in neighboring ranges and approached the San Juan Mountains, and possibly there were distinct glacial epochs in that period of glaciation.

After the retreat and disappearance of the early Tertiary ice, stream erosion continued, and the western portion of the San Juan Mountain area was reduced to a surface of slight relief which may be thought of as a peneplain.[1] This peneplain bordered on the west a higher area of mountainous character, which supplied the material for the Telluride conglomerate. The deposition of gravels upon this peneplain surface was probably due to some uplift and rejuvenation of the streams in the eastern portion of the range. After the deposition of the Telluride conglomerate there was further erosion in the range, and then came the three great epochs of volcanism, the San Juan, the Silverton, and the Potosi. During these epochs of volcanism a great volcanic plateau was developed. By this time the Miocene epoch had been reached and possibly passed, and with the quieting down of volcanic activity began the erosion and dissection of the volcanic plateau. During this period of dissection another generation of San Juan Mountains was carved, this time out of volcanic débris and great lava flows (see fig. 1).

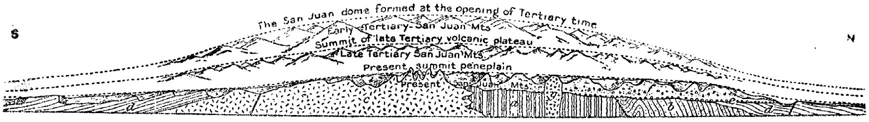
S
N
The San Juan dome formed at the opening of Tertiary time
Early Tertiary San Juan Mts
Summit of late Tertiary volcanic plateau
Late Tertiary San Juan Mts
Present summit peneplain
Present San Juan Mts
a
b
c
d
e
f
g

FIG. 1. DIAGRAMMATIC CROSS SECTION SHOWING THE PHYSIOGRAPHIC EVOLUTION OF THE SAN JUAN REGION SINCE THE BEGINNING OF TERTIARY TIME. *a*, PRE-CAMBRIAN SCHIST AND GNEISS; *b*, ALGONKIAN QUARTZITES; *c*, PRE-CAMBRIAN GRANITE INSTRUSION; *d*, PALEOZOIC AND MESOZOIC ROCKS; *e*, RIDGWAY TILL AND TELLURIDE CONGLOMERATE; *f*, MIDDLE AND LATE TERTIARY VOLCANICS; *g*, TERTIARY INTRUSIVES.

Recent physiographic studies of the range have led to the recognition of a summit peneplain in the San Juan region (see fig. 1), so it would appear that the first dissection stopped at a plain which is now represented by many of the summit areas within the region. The San Juan Mountains that were first carved out of this great volcanic plateau should then be thought of as surmounting those of today. Perhaps, if replaced, they would rise 3000 or 4000 feet above the present summits (see fig. 1).

With the redoming of the area, which involved the warping or doming of the summit peneplain, another cycle of erosion was begun. Valleys were again formed, and in these valleys snows collected which in time formed glaciers that advanced to the lowlands bordering the range. These earliest Pleistocene glaciers retreated and disappeared. The range continued to be uplifted, and the streams were so rejuvenated that they cut great canyons below the broad troughs occupied by the Cerro glaciers. Again climatic changes favored the formation of ice among the summits, and that ice (the Durango glaciers) descended through the main canyons to the foothills and later retreated and disappeared. The canyons were still more deeply cut into the mountain mass, and then climatic conditions favorable for glaciation once more returned and the Wisconsin or third series of Pleistocene glaciers formed and descended through the great canyons, nearly as far as those of the Durango stage. These glaciers have now disappeared, and there is no true glacier ice remaining in the region today, but the streams are vigorously dissecting the mountain mass to still greater depths. The vigor of that work is illustrated in many a sharp, V-shaped notch cut below the depth of ice action. The débris taken from the mountin area is being distributed along the great valleys leading away from the range.

The ice gouging of the three successive Pleistocene stages and the vigorous stream work during the interglacial intervals and since the last melting away of the ice suggest somewhat continuous mountain growth in this region during late geological time.

The physiographic study of the San Juan region has associated with it much that is of human interest. As the region has passed through successive cycles of erosion the position of the ground-water table in the great mountain mass has necessarily changed. The base of the surface zone of oxidation has therefore shifted. With the deepening of erosion and the drawing off of ground waters larger portions of the ore bodies have come to be within the surface zone of oxidation. Secondary enrichment may, therefore, have proceeded to greater and greater depths as the erosion history has progressed. This suggestion has come from the study of the physiographic history of the San Juan Mountains, but as secondary enrichment seems to have been of minor importance here, the idea must be tested in other regions that have similarly passed through several cycles of erosion, and where the secondary enrichment of ore bodies has been recognized as of greater significance.

Settlement was first made in the mountains by those seeking the mineral deposits, and the largest settlements now are mining towns. They are Ouray, Telluride, Silverton, Lake City, Creede, Rico, and Durango. About the margin of the range where agriculture has become of greater importance, and where fruit raising has been especially developed, are the towns of Montrose, Ridgway, Mancos, Ignacio, and Del Norte.

As the lowlands bordering the range have been taken up for settlement, and the broader valley bottoms within the mountains have been fenced in for ranch lands, there has come a demand for a large amount of water for irrigation purposes. Glacial lakes, in many instances, have been modified so as to form great reservoirs, and certain of the canyons have been dammed so that the surplus waters from the melting snows and heavy rains may be stored and held until late in the growing season.

The mountain slopes, where they are not too steep or too high, are clothed with magnificent forests. These are now under national control, and the ranchmen are assigned portions where they may graze their cattle, and in other portions, especially in the higher mountain areas and often in the glacial cirques or basins, thousands and thousands of sheep may be cared for during the summer. In return for this a fee is paid to the national government on a per capita basis. Where timber is cut either by the settlers or by lumbermen for commercial purposes, it is cut under the supervision of those in charge of the national forests.

At the southwest base of the range is that region of remarkable human interest now set aside as the Mesa Verde National Park. It is one of the homes of the ancient cliff dwellers. The physiographic study of the Mesa Verde region indicates that the canyons in which those people built their homes were cut during and since the last glacial period. It is evident from the study of those homes that hundreds of not thousands of people once lived on this mesa. Today there is but a single spring, and that is near one of the smaller settlements. The articles found about these homes indicate that the people raised corn and cotton, and found in the chase an abundance of deer. Today the region is without game, and all the evidence available indicates that when the region was populated there was a much more moist climate. That does not prove that the cliff dwellers occupied those homes while there were glaciers in the mountains, but it is possible that our southwest country was inhabited by men at that time. The records from anthropology and geology are coming closer and closer together, and the further study of this portion of the continent from both points of view may lead to discoveries of unusual interest.

The study of the geography of this region has necessarily a very close relationship to the geologic studies of the range, but it may lead also to a study of anthropogeography, and to a study of how the present geographic conditions are influencing the settlement and commercial development within this district.[2]

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[1] Whitman Cross, U. S. Geol. Survey Geol. Atlas, Silverton folio (No. 120), 1905.

[2] This study is here published with the permission of the Director of the U. S. Geological Survey.

THE AGE OF THE MIDDLE ATLANTIC COAST UPPER CRETACEOUS DEPOSITS

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Distribution.—The Upper Cretaceous formations of the Middle Atlantic Coast area are most extensively developed in New Jersey from which state they thin rapidly to the northward through the islands off the New England coast, only a few remnants being left in southern Massachusetts; while to the south they gradually disappear, only the lowermost reaching the Potomac drainage basin. Beyond this point they have only been recognized in deep-well borings in Virginia although the deposits probably extend continuously beneath the mantle of Tertiary formations until they again appear in surface outcrops in the South Atlantic area.

Divisions.—Several formations have been recognized within the area of outcrop and have been designated under the names of Raritan, Magothy, Matawan, Monmouth, Rancocas, and Manasquan.

Numerous minor subdivisions have been described in New Jersey but have been unrecognized elsewhere. All the deposits are of shallow-water origin as shown by their contained faunas. The relatively slight differences in the faunas of these smaller units are evidently due to the varying proximity of stream mouths and sediment-bearing currents rather than to any differences in depth which may have existed.

The major divisions, on the other hand, are based on distinct differences in the faunas and floras which may be recognized when present not only in the Middle Atlantic Coast area but throughout the South Atlantic and Gulf regions as well.

The Raritan and Magothy formations are clearly separable on the basis of their contained floras while the Matawan and Monmouth, the only marine divisions with equivalents in the South Atlantic and Gulf